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Report 1985-2

Evidence of Yellow Pickerel (Stizostedion vitreum vitreum) Reproduction in the Central Basin of Lake Erie, 1984

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ABSTRACT

To determine if yellow pickerel (walleye) (Stizostedion vitreum vitreum) were reproducing in the central basin of Lake Erie, a study was conducted in 1984 to document the occurrence of mature and spent walleye followed by sampling designed to detect walleye eggs, larvae and juveniles at selected sites.

Mature and spent walleye were observed in the commercial catch as far east as Plum Point with spawning occurring on or after May 7. Of those fish eggs collected during the sampling period between May 14 and May 31, none were positively identified as being walleye eggs. Larval walleye were sought from May 31 to June 28. Larval walleye ranging in total length from 6.5 mm to 8.0 mm were captured only on May 30 and 31. The most easterly occurrence of larval walleye was 4.8 km east of Port Glasgow. Juvenile walleye were sought from July 10 to August 1. Juvenile walleye ranging in total length from 51 mm to 75 mm were caught from July 24 to July 31. The most easterly occurrence of juvenile walleye was Port Glasgow.

Walleye appeared to experience some degree of reproductive success in the western part of the study area (vicinity of Erieau) as evidenced by the presence of mature then spent adults in May, larval walleye in May and juvenile walleye in July. Although concentrations of mature then spent adults were observed as far east as Plum Point, no confirmation of survival was obtained through capture of larval or juvenile stages further than 4.8 km east of Port Glasgow.

INTRODUCTION

In recent years, the commercial harvest of yellow pickerel (walleye) has increased in the central basin of Lake Erie (MNR 1984b). This has led to speculation that there has been a re-establishment of a central basin spawning population. In earlier years, commercial fishermen harvested walleye that were in spawning condition from inshore waters between Wheatley and Erieau (Krause 1967; Tiessen 1967). This area was considered by commercial fishermen to be a minor spawning area.

In 1984, the Lake Erie Fisheries Assessment Unit (LEFAU) initiated a study to determine if walleye were reproducing in the central basin. The study was designed to collect circumstantial evidence of reproduction by documenting occurrences of mature and spent walleye followed by sampling procedures designed to collect walleye eggs, larval walleye and juvenile walleye at selected sites in the central basin.

DESCRIPTION OF THE STUDY AREA

The study area was confined to part of the Canadian waters of Lake Erie's central basin. The study area was bounded on the west by waters in grid locations 2138, 2128, 2118, 1198, 1188 and 1178 and on the east by waters in grid locations 2278, 2268, 2258, 2248, 2238 and 2228 (MNR 1984a) (Figure 1). The study area is within fishery statistical districts OE-2 and OE-3 (Smith et al 1961).

The shoreline within the study area consists of beach or dune complex around Erieau and the Rondeau peninsula; however, much of the shoreline consists of bluffs higher than 3 meters (Haras and Tsui 1976).

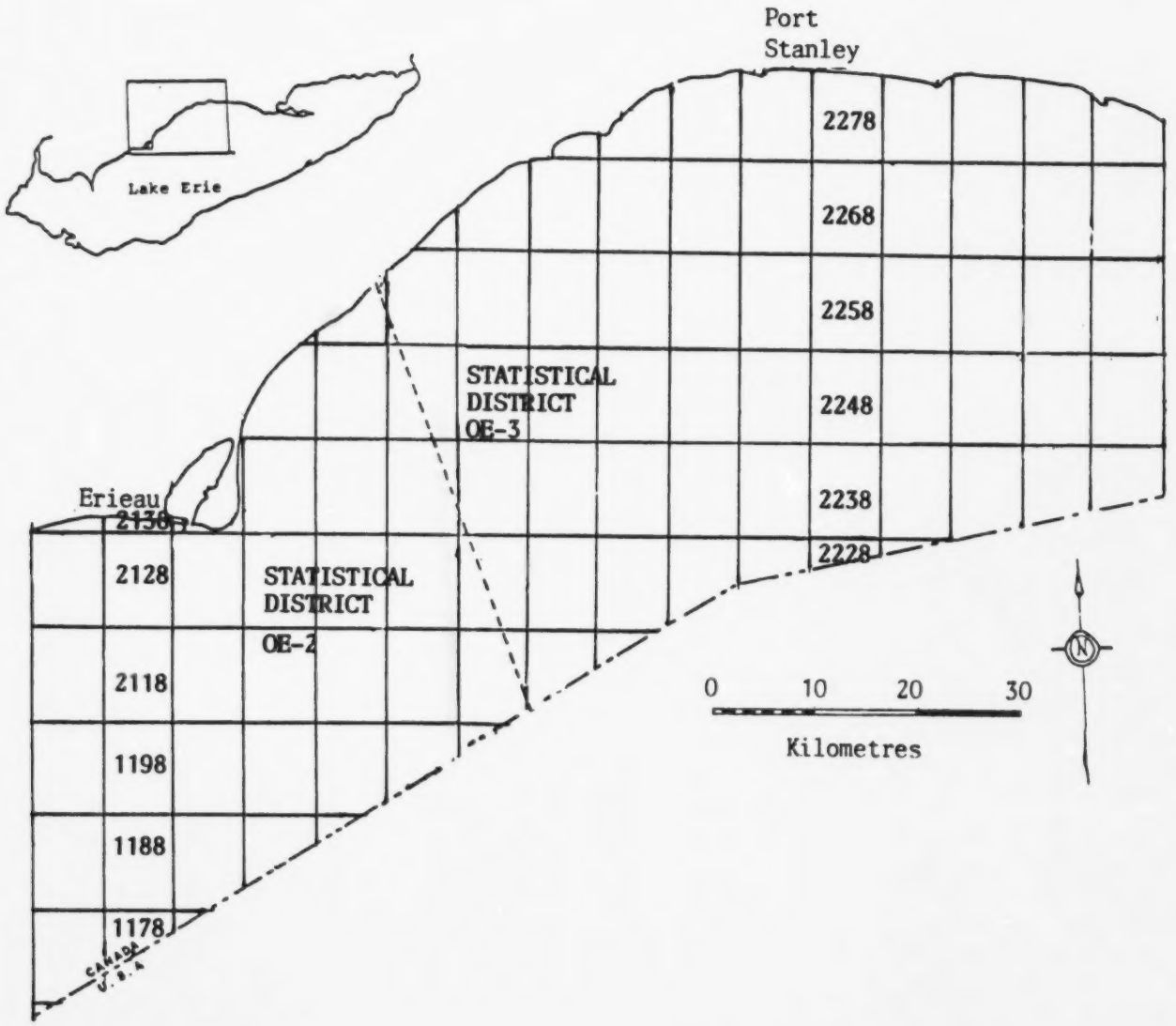

Figure 1. The Study Area.

METHODS

Occurrence of Mature and Spent Walleye

Between April 25th and May 11, 1984, walleye from the catches of commercial fishermen operating out of Erieau and Port Stanley were examined. Larger fish, those more likely to be mature, were chosen for examination. Scale samples were taken and length measurements, sex and sexual maturity were recorded for each fish. When permitted, the gonads were examined and sex and sexual maturity determined using criteria described by Eschmeyer (1950). Otherwise, sex was determined by expulsion of milt or eggs and fish were classified as being:

immature or maturing - fish with hard gonads, gonadal products not free-flowing;

ripe - fish with free-flowing gonadal products; or

spent - fish with soft gonads and only residual gametes visible.

Catch location was provided by the boat captain and was expressed as a number representing the code for the Lake Erie Commercial Fishing Grid (MNR 1984a). Each grid measures five minutes of latitude by five minutes of longitude (9.2 x 6.8 km) covering an area approximately 63 km^2.

Occurrence of Walleye Eggs

Egg collection was conducted from May 14 to May 31, 1984. Sample site selection was influenced by the location of ripe walleye encountered earlier in the study, by suggestions from commercial fishermen and by substrate suitability. Sample sites were located in nearshore waters stretching from

south of Morpeth (latitude 42°22'20", longitude 81°49'10") in the west to near Plum Point, Elgin county (latitude 42°36'23", longitude 81°23'44") in the east (Figure 3). The shoreline in this area is characterized by high bluffs which are composed predominantly of clay tills. They have little beach protection, and are therefore susceptible to high erosion rates from wave action (Gelinas and Quigley 1973); however, that portion of the shoreline near Patrick and Plum Points experiences less wave action and is composed of coarser sand and gravel tills, producing the lowest erosion rates in the study area (Gelinas and Quigley 1973). Sampling site selection was made in a systematic fashion to cover the largest possible area but particular attention was paid to the area near Patrick Point (Station E17) because it had yielded commercial yellow perch and walleye catches during the spawning season in the past (A. Grayling, pers. comm. 1984) and because it appeared suitable as a spawning substrate.

Port Glasgow (latitude 42°30'23", longitude 81°36'37") was used as operations base for both the egg collecting and larval fishing phases of the study because of its central location. A charter boat operator was hired because of his knowledge of the local waters and his boat which was ideally suited for the work. The boat was a 12-m steel hulled vessel.

Egg samples were collected using a Goulds Model 3677 Utility Pump (Series DU) powered by a 2.2 kW Briggs and Stratton motor with a flow rate of 500 l/min. The pump was fitted with varying lengths of 5.1-cm inside diameter flexible irrigation hose. The intake end of the hose was equipped with a slotted screen with openings of 21 x 6 mm. Each sample consisted of

materials separated from the pump effluent during a ten-minute sampling period. The operating pump was moved along a transect beginning in shallow water and proceeding offshore perpendicular to the shore line. The intake hose was dragged along the substrate at speeds of 1.6 - 3.2 kmph while the effluent was strained through two nested screens 45.7 cm sq x 11.4 cm deep. The upper screen measured 8 meshes to 2.54 cm while the lower screen measured 14 meshes to 2.54 cm. Pumped material and echo sounder tracings provided an indication of substrate type.

All eggs and benthic invertebrates were removed from the screen and the percent of live eggs was estimated. Translucent eggs and those exhibiting embryonic development were considered live, while opaque and fungus covered eggs were considered dead (Eschmeyer 1950; Johnson 1961; Manz 1962). Eggs were immediately cleared in Gilson's solution and later preserved in 10% formalin (Ricker 1971). A more detailed examination of eggs was made using a Leitz-Wetzlar binocular dissecting microscope to determine the number of live eggs and to measure undamaged eggs. Eggs were submitted to the National Museum of Natural Sciences, Ottawa, for identification.

Eggs collected from station E17 (Patrick Point) were incubated to enable identification of the hatched fry. Eggs were placed in a 1-l beaker filled with lake water at ambient temperature and were kept aerated. They were observed daily to detect hatching.

Occurrence of Larval Walleye

Based on the observed maturity of sampled adult walleye and a reported hatching time of 12-18 days (Scott and Crossman 1973), larval fishing was scheduled for two days a week from May 30 to June 28, 1984.

Sampling was conducted along the north shore of Lake Erie from the Morpeth area (latitude 42°22'20", longitude 81°49'10") in the west to as far east as Plum Point (latitude 42°36'23", longitude 81° 23'44") (Figure 4).

Some sample sites were chosen because eggs were found there earlier. Other sites were chosen because their gravel or rubble substrates appeared suitable for spawning or because spawning activity was suspected.

The fishing gear consisted of a 3.35-m long conical net attached to a steel ring 12.7 mm in diameter. The ring had an inside diameter of 1.00 m making the effective fishing area 0.785 m^2. The net tapered to 7.62 cm at its distal end which had a PVC coupling attached to it. The cod end consisted of a 22-cm length of 7.62-cm PVC pipe capped with a plexiglass disk and was attached to the net by screwing it into the PVC coupling. The 1-l capacity cod end had screen-covered straining windows cut into the pipe wall. The net was made of 526 µ mesh size nylon monofilament cloth. The straining windows of the cod end were covered with this same material. A 4.9-kg depressor foil, which was attached to the bottom of the steel ring, maintained the net opening in a vertical position when fishing.

The net was towed from a boom protruding laterally from the boat to avoid propeller turbulence. Depth of the net in

the water column was determined by the length and angle of the tow line. In deeper water, chains were tied to the bottom of the steel ring to bring the net down.

Surface, midwater and bottom tows were made with tows being 5 minutes long. They were made parallel to shore at a boat speed of approximately 1 m/sec. Water depth was recorded from the echo sounder at each site and surface water temperature was taken with a thermometer at most sites.

After each tow, the net was washed down with water and the collected material was fixed in 5-10% formalin before the next tow. Later, larval fish were sorted from plankton and preserved in 10% formalin. Specimens from each tow were identified and counted and larval walleye were measured.

Occurrence of Juvenile Walleye

As the season progressed, increasing intensity of plankton blooms interfered with the plankton net's efficiency to catch larval fish. In addition, as young walleye grow they undergo a transition from a post-hatching pelagic existence to an inshore, demersal mode (Eschmeyer 1950; Johnson 1969; Bulkley et al 1976; Forney 1976; Ryder 1977). Priegel (1970) found that as fry increased in size, their ability to avoid a meter net increased and they were not easily captured especially when the net was not fishing efficiently because of zooplankton blooms. Consequently beach seining and trawling were used from July 10 to August 1, 1984 to attempt the capture of juvenile walleye.

Although a small portion (≈25%) of the lake shoreline within the study area consisted of sand beaches, a much larger portion consisted of bluffs higher than 3 meters (Haras and

Tsui 1976). Consequently much time was spent seeking access points to the water by foot or with a small (4.3-m) aluminum motor boat. Topographical maps, Ministry of Transportation and Communications County road maps and the 1973 Canada-Ontario Great Lakes Shore Damage Survey Coastal Zone Atlas were used as aids in locating potential access points.

Each shoreline sampling site for beach seining was chosen based on:

its accessibility;

its proximity to areas where suspected walleye eggs or larval fish had been found during earlier phases of the study;

its physical suitability for seining; and

its suitability as a walleye nursery area.

Two seining methods were used. The first involved using a 9.1-m long and 2.1-m deep seine net. The seine was set out perpendicular to and then moved parallel to the shore for 20 m with the shore end of the seine no more than 2 m from shore. After being pulled parallel to the shore for 20 m, the offshore end of the seine was pulled toward shore in an arc and both ends were pulled up on the beach simultaneously. The maximum depth of water (approximately 1.5 m) that could be seined using this method was limited by the height of the operator on the offshore end of the seine. This hand-set method was used in 15 of the 21 seine hauls.

When no young-of-the-year (YOY) walleye were found in shallow water, an 18.3-m long by 2.1-m deep seine was used to sample larger areas in deeper water. Lengths of rope 30.5-m

long were tied to each end of the seine. Using a 4.3-m aluminum boat powered by a 7.4-kW outboard motor, the seine was set out parallel to the shore and 30.5 m offshore. Both ends of the seine were drawn simultaneously to the beach by hand. With this method the depth of water seined was limited only by the length of the ropes and in this case seines were made in water up to 3.1-m deep. Boat-set seining was used in six of the 21 seine hauls. Both seines were nylon and had a mesh size of 0.56-cm stretched measure. Both seines were designed to fish on the bottom in water depths greater than the depth of the seine (2.1 m). All seining was done in daylight hours. Water depth, substrate type and surface water temperature were recorded before each seine haul.

Captured fish were sorted and YOY were identified. Abundance of the predominant species in the catch was estimated. Samples containing species difficult to identify were subsampled and preserved in 10% formalin or iced down for later identification. All YOY walleye were measured and preserved in 10% formalin.

Bottom trawling was carried out at locations which had been sampled with the beach seine and were within an hour, by water, of a boat launching facility. Boat launching facilities were available at the Erieau marina, Rondeau Bay near the Rondeau Provincial Park main office, Rondeau Park near the Interpretive Centre and at Port Glasgow. The launch ramp near the Interpretive Centre proved to be difficult to use during rough water conditions; consequently, launching facilities at Erieau and Rondeau Bay were used for the Erieau-Morpeth sites while Port Glasgow was used for the Port

Glasgow site.

All sites were adjacent to sand or sand and gravel beaches. The echo sounder on the boat was used to locate flat-bottomed, obstacle-free areas suitable for bottom trawling. An attempt to trawl in areas adjacent to the clay bluffs, which dominate the shoreline in the study area, was abandoned when the net fouled on irregular substrate.

Trawl sampling was done with a bottom trawl having a head rope length of 6.1 m, with a mouth opening of 1.0 m in height and made of 3.8-cm stretched mesh nylon web with a 1.3-cm stretched mesh cod end. The trawl was pulled behind a 6.1-m fiberglass boat powered by a 140-kW inboard-outboard engine at an engine speed of 1600 RPM. The standard sampling duration was 5 minutes; however, the trawling time was shortened on two occasions when the net became fouled on bottom. Trawls were made from 50 to 150 m offshore and parallel to shore in waters from 1.8 - 4.6 m deep.

Water depth and surface water temperature were recorded before each trawl. Water depth was obtained from the depth sounder in the boat and surface temperature was obtained with a hand held thermometer. All YOY walleye were measured and preserved in 10% formalin.

RESULTS AND DISCUSSION

Occurrence of Mature and Spent Walleye

Between April 27 and May 11, 1984, 164 walleye were examined from catches of commercial fishermen operating from Erieau and Port Stanley. All walleye were caught in an area from southwest of the village of Erieau (grid 2128) eastward to an area east of Port Stanley (grid 2278)(Figure 2). Walleye were observed in several stages of sexual maturity and the progression from predominantly maturing fish to spent fish during this period was documented (Table 1). The sex of 5.5% of the fish could not be determined. Throughout the sampling period females were more abundant than males, probably as a result of selection of larger fish for sampling.

Seven year-classes (ages two through eight) were represented with no year-class appearing to be dominant (Table 2). All males were mature by age two. Females at age three, four and five were 20.7%, 80.5% and 100.0% mature respectively.

On May 7, ripe and spent males and females were caught together in the same nets (Table 1). Prior to May 7 there were no spent fish caught and on or after this date 54.8% of the mature fish were spent, suggesting that spawning took place on or after May 7, 1984.

Of those fish that were maturing, ripe, or spent, 92% came from three areas: 28% came from an area 5-10 km southwest of the village of Erieau (grid 2128), 44% came from east of the Rondeau peninsula (grids 2230 and 2240) and 20% came from an area off Plum Point (grid 2275) (Figure 2).

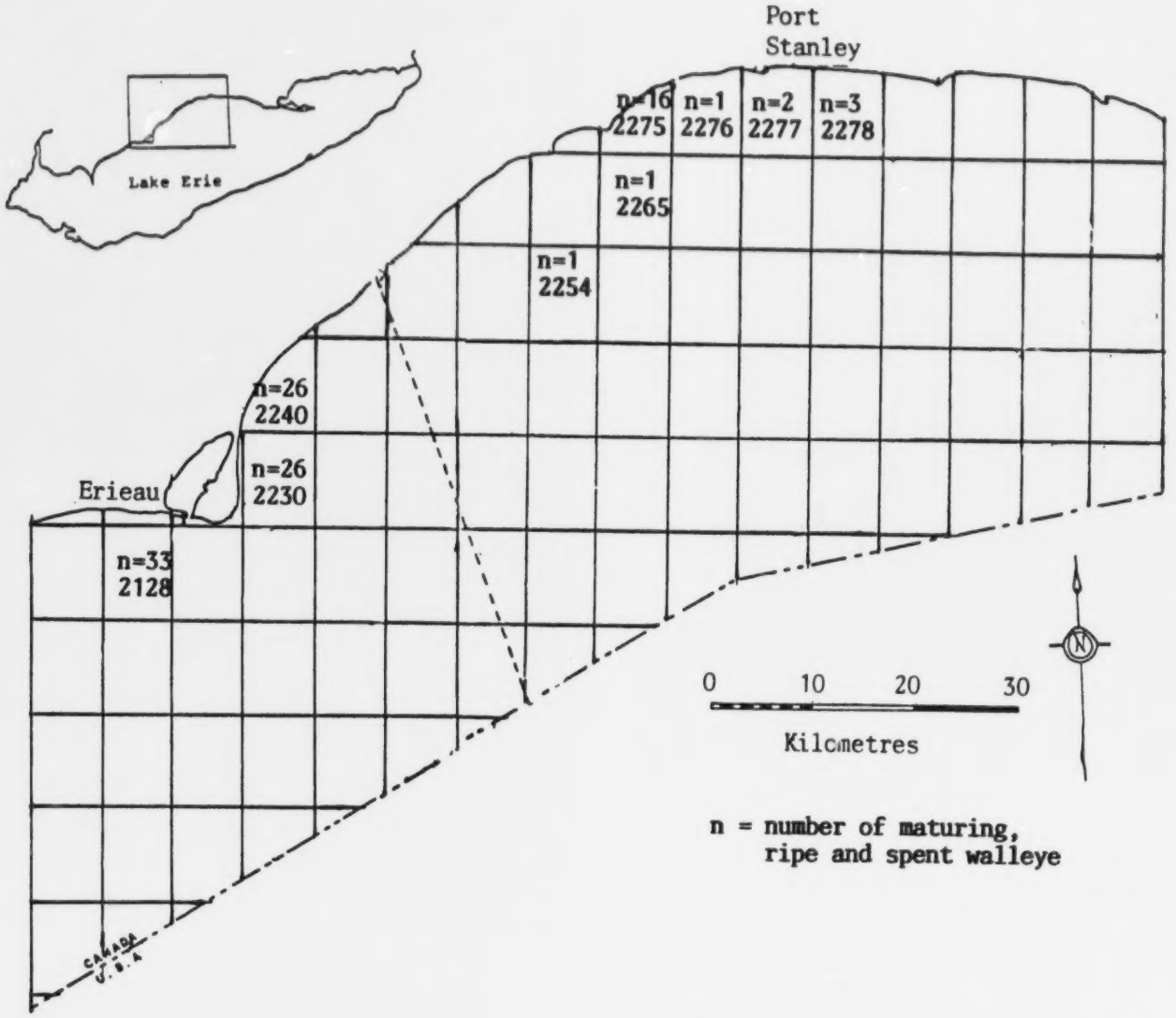

Figure 2. Capture site (grid location number) and numbers of maturing, ripe and spent walleye sampled from the central basin, Lake Erie, 1984.

Occurrence of Walleye Eggs

A total of 37 samples were collected at 19 sampling stations (Appendix 1) along the north shore of the central basin of Lake Erie from May 14 to May 31, 1984 (Table 3) (Figure 3). Sampling depths ranged from 1.2 to 7.9 m. Surface water temperatures during the sampling period ranged from 7.2 to 8.9°C.

Eggs were present in 28 of the 37 samples. Numbers of individual eggs in each sample ranged from 1 to 79, the largest numbers being taken at stations E17 and E19. The percentage of live eggs ranged from 60% to 100% for those samples containing more than ten eggs. Olson (1966) noted that it is often difficult to distinguish dead infertile eggs from fertilized ones during the first 4 days of parthenogenic development and these values should therefore be considered estimates.

In addition to the individual eggs, two samples, at stations E3 and E4, contained gelatinous masses of eggs which were identified as those of yellow perch (Perca flavescens) and appeared to be in early stages of development.

The mean diameter of all individual eggs collected was 1.79 mm (range 1.5 - 2.2 mm). These eggs were in various stages of development.

From the 104 eggs incubated in the laboratory, four larvae were hatched (two on June 4, one on June 2 and one on June 6). Three of the larvae were identified as trout-perch (Percopsis omiscomaycus) and the fourth was damaged. Many of the eggs developed a Saprolegnia-like fungus after incubation started. Hurley (1972) noted that Saprolegnia invaded live eggs

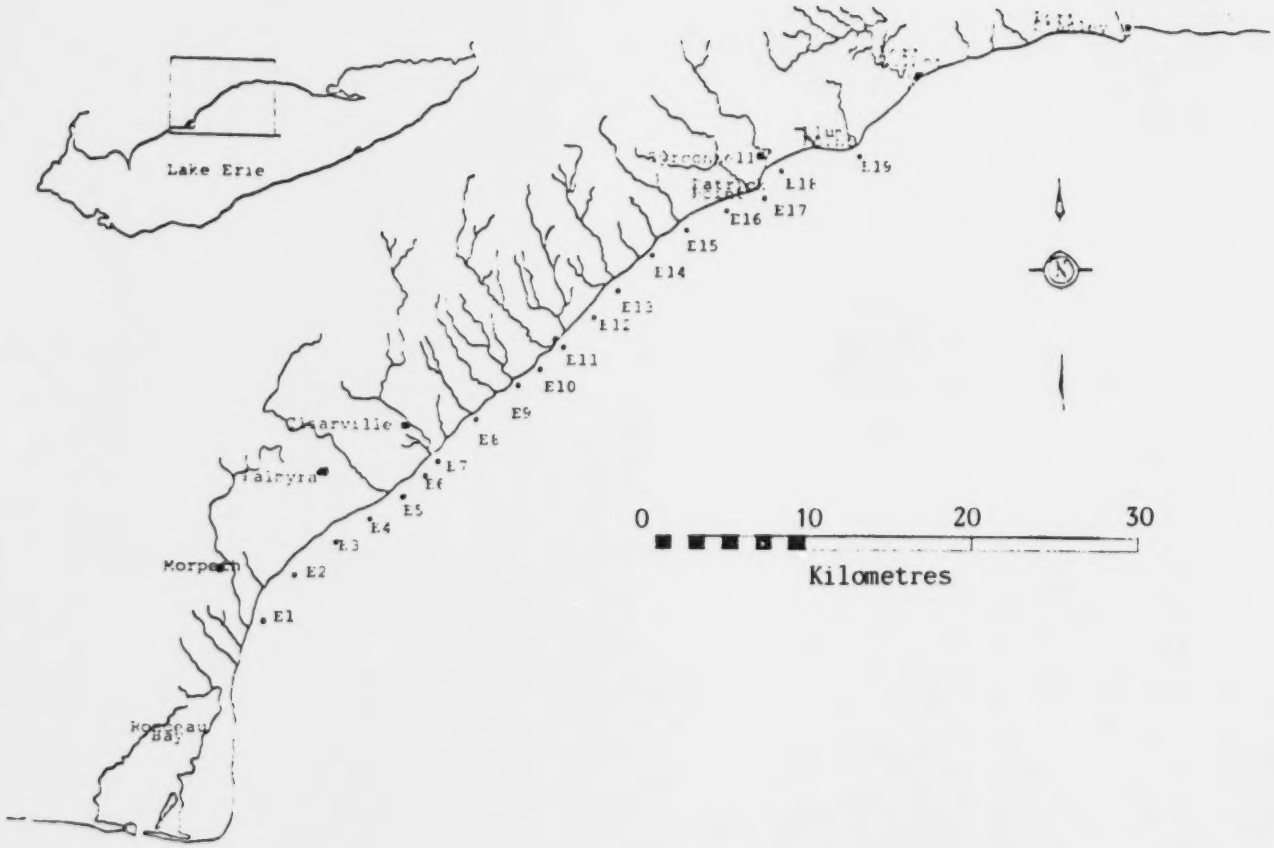

Figure 3. Walleye egg collection sites in the central basin, Lake Erie, 1984.

causing them to clump together with dead eggs and eventually die.

Studies of walleye stocks in Lake Erie have dealt primarily with those in the western basin (Wolfert 1969; Busch et al 1975; Van Vooren 1978); some specifically investigated eggs on spawning sites (Manz 1962; Baker 1971; Wolfert et al 1975). There has been little documentation of walleye spawning success in the Canadian waters of the central basin of Lake Erie and background data are scarce (Goodyear et al 1982).

The largest numbers of eggs were found at stations E17 and E19, at Patrick Point and Plum Point respectively, in water 1.5 to 6.1 m deep. The substrate in these areas was identified as hard bottom with little gravel (Table 3) and corresponds to a section of the shoreline of the central basin with the lowest erosion rates and the least wave action (Gelinas and Quigley 1973). Baker (1971) studied the western basin and found the largest numbers of walleye eggs at stations less than 4.6 m over rocky bottoms. Eschmeyer (1950) reported walleye spawning primarily in areas of gravel, rubble and boulders and Johnson (1961) found that egg survival was best on a clean gravel-rubble bottom, intermediate on firm clean sand bottom and poor on soft muck-detritus bottom. In addition both Eschmeyer (1950) and Johnson (1961) noted movement of eggs by wind and wave action which resulted either with eggs washed up on shore or transported to deeper water and deposited on less desirable substrates. One can assume that the combination of desirable substrates and preferred water depths coupled with reduced wave action in the area of

Patrick and Plum Points would indicate desirable spawning habitat for walleye. The occurrence of large numbers of eggs in this area would seem to support this assumption. It was not possible to confirm that eggs collected were those of walleye as the only species hatched when incubated in the laboratory were trout-perch .

Walleye and trout-perch eggs are similar in morphology both having an anteriorly positioned oil globule approximately 0.6 mm in diameter and their size ranges overlap. Although the only larvae hatched from eggs in this study were trout-perch, the mean diameter of all eggs (1.79 mm) more closely resembled that of walleye eggs than trout-perch eggs. Scott and Crossman (1973) report that walleye egg diameters measure 1.5 - 2.0 mm while Auer (1982) reports ranges of 1.9 - 2.3 mm and 1.5 - 2.1 mm for walleye eggs from two different sources. Nepszy (pers. comm. 1984) found "fresh" walleye eggs from the Thames River had a mean diameter of 1.98 mm (range 1.89 - 2.11 mm) while the eggs in this study had a mean diameter of 1.79 mm (range 1.5 - 2.2 mm). Trout-perch eggs have a reported mean diameter of 1.3 - 1.9 mm (Auer 1982) the upper limit of which falls below the maximum found in this study. The presence of walleye eggs in the samples could account for a larger mean diameter and broader range than normally associated with trout-perch. The occurrence of walleye and trout-perch as well as other species spawning in the same area at the same time has been recognized by other investigators. Savoie (1984) documents walleye, suckers (Catostomus commersoni) and trout-perch in the Napanee River during a ten-day period of the spawning run.

Johnson (1961) found sucker and yellow perch eggs together with walleye eggs in Lake Winnibigoshish, Minnesota. Walleye eggs have also been found with sucker eggs in the Talbot River in Ontario (McElman and Balon 1979).

Yellow perch eggs were collected on two occasions during this study and were easily identified by their characteristic gelatinous egg mass which is unique to that species (Scott and Crossman 1973). Sucker eggs, which are white with no oil globule, have a diameter of 2.5 - 2.82 mm unfertilized and swell to 3 mm after fertilization (Fish 1932). No eggs of this size range were found in this study although eggs submitted to the National Museum of Natural Sciences were identified as trout-perch eggs, sucker eggs and some unidentifiable eggs (Faber, pers. comm. 1985).

The problem remains in this study to distinguish between trout-perch and walleye eggs. Savoie (1984) also recognized the need to distinguish between walleye and trout-perch eggs (among others) which are likely to occur on similar bottom types at the same time of year.

Until embryos from those eggs in late stages of development can be positively identified there is only circumstantial evidence of walleye egg deposition at the sites investigated in this study.

Occurrence of Larval Walleye

The location of sites sampled to document the occurrence of larval walleye is presented in Appendix II and Figure 4. A total of 43 tows were made at 12 sites from May 30 to June 28, 1984 and 1,621 larval fish were caught. Rainbow smelt (Osmerus mordax) and yellow perch contributed 54.8% and 42.3% by numbers of the

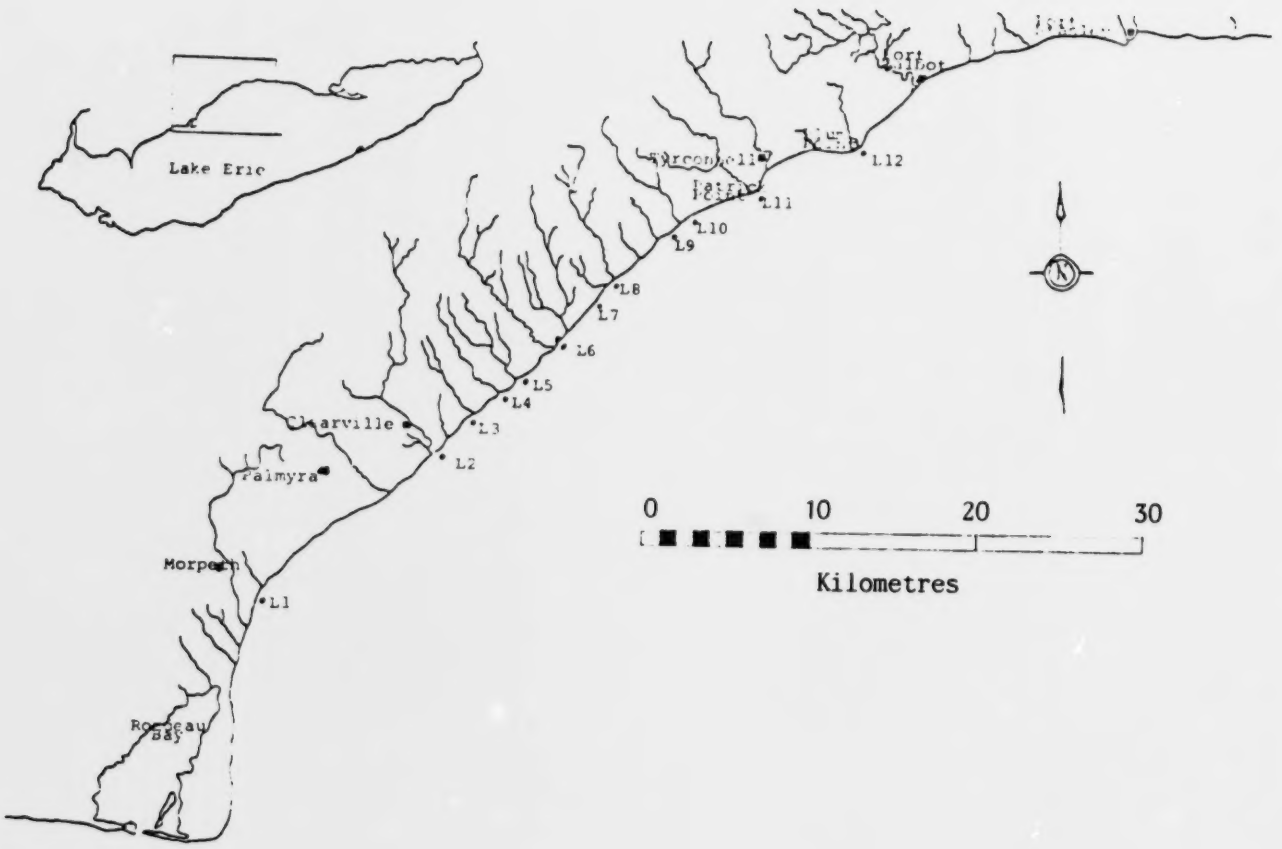

Figure 4. Larval walleye collection sites in the central basin, Lake Erie, 1984.

total catch respectively (Table 4). The remaining 2.9% consisted of trout-perch, burbot (Lota lota), walleye, members of clupeidae, cyprinidae and percicthyidae families and unidentifiable fish. Four walleye were identified in three of the 43 samples. These larval walleye were caught at Clearville (L2) and Leith Fishery (L8)(Figure 4). Larval walleye were caught May 30 and May 31 close to shore in water 3.0 to 4.3-m deep with the net at or very close to the bottom. No walleye were caught after May 31, 1984. No walleye were caught in water depths greater than 4.3 m or in midwater or surface tows at any location. Walleye larvae were always caught in association with yellow perch and rainbow smelt but no other species.

Mean total length of the walleye was 7.25 mm (range 6.5 - 8.0 mm) and all walleye contained yolk (Faber, pers. comm. 1985).

Scott and Crossman (1973) report newly hatched walleye fry to be 6.0 - 8.6 mm long while Nelson (1968) and Faber (1967) found fry to be 6.13 - 6.88 mm and 7.0 - 7.5 mm long respectively. The yolk sac is absorbed after five days (Houde 1968; Preigel 1970) at a length of approximately 9.5 mm (Houde and Forney 1970). Based on the lengths (6.5 - 8.0 mm) and the presence of yolk sacs, it would appear that these walleye were only a few days old when captured on May 30 and 31. This is consistent with an estimated spawning date of May 7 or later and an expected incubation period of 12 - 18 days.

Newly hatched prolarvae are photopositive but a large yolk sac and poor swimming ability restrict the fry's movements. Occasional excursions to the surface are followed

by an immediate settling to the bottom (Houde 1968; Houde and Forney 1970). The fry's swimming ability improves as the yolk sac is absorbed and fry swim at the surface except in complete darkness when they stay on the bottom (Houde and Forney 1970). This "swim-up" stage has been reported by several authors to occur from as few as five days (Houde and Forney 1970) to as many as twelve days (Faber 1967) after hatching. Once near the surface, fry move into the limnetic zone of the lake where they lead a pelagic existence, feeding on zooplankton (Faber 1967; Johnson 1969; Houde and Forney 1970).

Apparently, after May 31, walleye larvae should have begun the swim-up and been more concentrated near the surface. Few mid-water or surface samplings were made after May 31. Future studies should schedule bottom, mid-water and surface samplings to reflect the expected fry locations.

Occurrence of Juvenile Walleye

Fourteen sites within the study area were found that were suitable for beach seining. A description of the location and directions to each of these sites are presented in Appendix III and Figure 5. Twelve of these sites could be sampled using either hand-set or boat-set seines since it was possible to carry the 4.3-m aluminum boat to the site with three people. It was difficult to get the boat to the water at sites S10 and S14 because of the steep gradient of the bluff. More sites could have been reached if the boat were used to travel among areas on a calm day.

Surface water temperatures ranged from 13.5 - 23.0^{o}C during beach seining (Table 5).

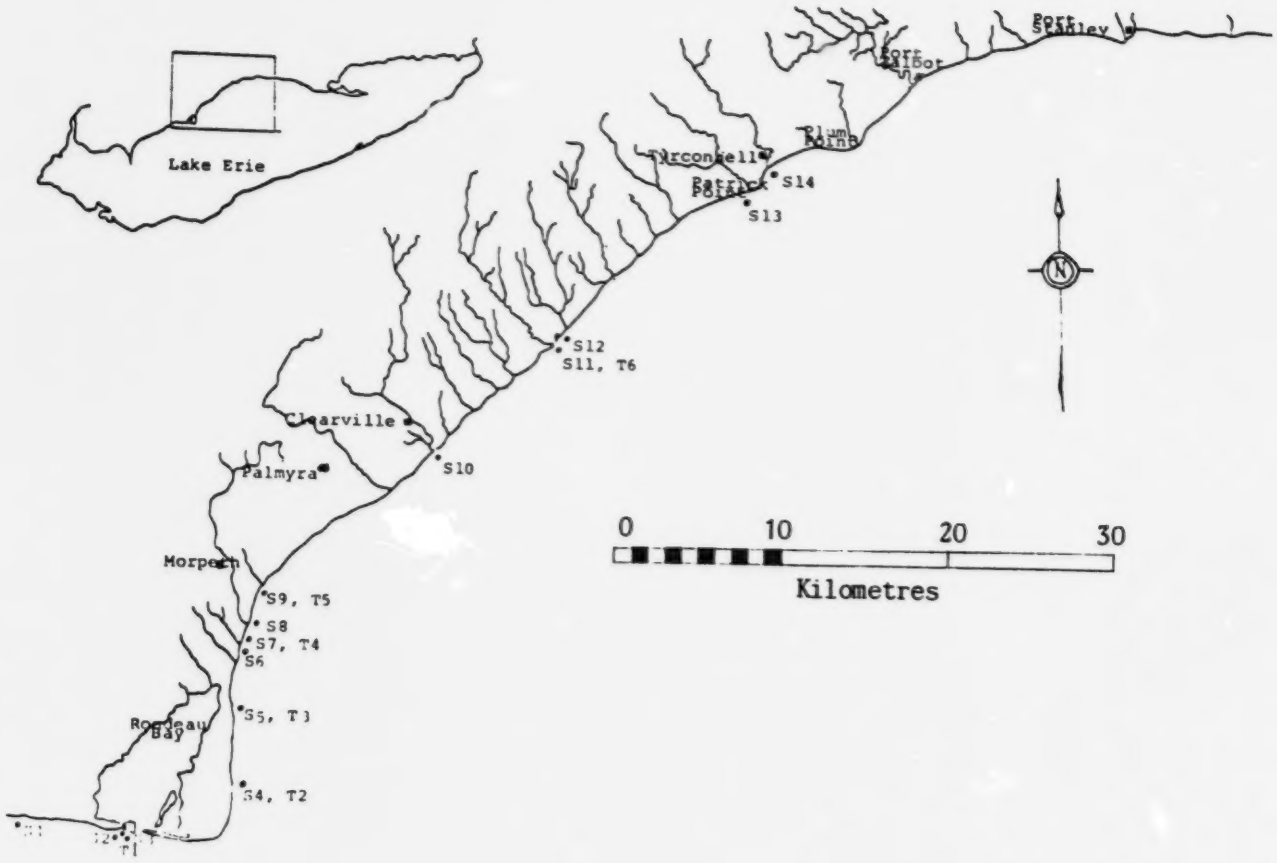

Figure 5. Juvenile walleye collection sites in the central basin, Lake Erie, 1984.

S1 - S14 Seining sites.
T1 - T6 Trawling sites.

Between July 10 and July 18, fifteen hand-set seine hauls at ten sites yielded YOY of a variety of fish (Table 5). Although numbers of each species were not recorded, the estimated catch composition in numbers was: yellow perch (50-60%), members of the clupeidae family (20-25%), smelt (10%) and white bass (Morone chrysops) and white perch (Morone americana) (10%). Other species made up the remaining 5-10% of the catch. No YOY walleye were caught using a hand-set seine net.

Six boat-set seine hauls were made on July 24 and 25 at six sites which yielded a variety of fish (Table 5). These hauls in deeper water yielded more YOY of captured species as well as adults of the cyprinidae family than did the hand-set hauls in shallower water. The number of each species was not recorded but an estimated 70-90% of the catch in numbers was YOY and yearling (YRL) yellow perch. Four YOY walleye were caught at three sites (S7, S9, S12) using the boat-set seine net. Their mean total length was 54.0 mm (range 51 - 58 mm). Water depths at locations where walleye were caught ranged from 0 - 3.1 m with surface water temperatures ranging from 19.0 to 22.5^{o}C. Walleye were always caught in association with yellow perch, gizzard shad (Dorosoma cepedianum), alewife (Alosa pseudoharengus) and white bass.

Many authors have observed a transition by walleye fry from a pelagic to an inshore demersal mode. Houde (1967) observed that the pelagic existence of walleye fry lasted for their first 4 to 6 weeks in Oneida Lake, New York until they reached a length of approximately 25 mm. Houde and Forney (1970) found that fry were limnetic for 5 weeks in Oneida Lake. Eschmeyer (1950) found evidence that fry in Lake

Gogebic, Michigan, lead a pelagic life until they reach a length of about 25 mm when they move inshore (late June - early July). Johnson (1969) captured 25 mm long fingerlings with seine nets inshore in 0.3 - 1.2 m of water in Little Cutfoot Sioux Lake. Forney (1976) concluded that in Oneida Lake the transition to the demersal mode begins in June when young have attained a length of 35 mm and is usually complete by mid July when fingerlings average 60 mm in length. Post larval walleye 25 - 30 mm long frequented the littoral zone and sometimes were found nearshore in shallow sheltered bays (Ryder 1977). Preigel (1970) however observed that YOY walleye did not frequent nearshore areas at any time during their life in Lake Winnebago, Wisconsin.

Several authors (Maloney and Johnson 1955; Forney 1966; Johnson 1969) have observed a gradual offshore migration of YOY walleye into deeper water as the summer progresses. Priegel (1970) and Forney (1976) also found that once walleye had attained a length of 35 mm, they could be captured by bottom trawling in open water areas of lakes. This is consistent with the findings of Bulkowski and Meade (1983) who found that, under laboratory conditions, walleye at 9 weeks of age (30 - 35 mm long) could be described as negatively phototactic and presumably would seek waters of decreasing light intensity. The change to negative phototaxis was more closely related to length than to age.

Seining results indicated that walleye had reached a length where they could be inhabiting deeper water. The trawl was used to attempt walleye capture in deeper areas.

Eight samples were taken on July 31 and August 1, at six

sites by trawling (Appendix IV) (Figure 5). Surface water temperatures ranged from 20.0 to 22.0°C (Table 6).

A total of nine species were captured with YOY yellow perch and YOY white perch comprising a large portion of the catch at all sites (Table 6). Two YOY walleye, whose total lengths were 62.0 and 75.0 mm, were caught at two of the six sites (one each at T1 and T4). Water depths at these sites ranged from 1.8 to 4.6 m and surface water temperatures ranged from 21.0 to 22.0°C. These walleye were caught in association with six species of fish including YOY and YRL yellow perch, YOY white bass, YOY and YRL white perch, YOY gizzard shad, YOY smelt and adult trout-perch (Table 6).

CONCLUSION

The occurrence of mature walleye in the commercial catch in the vicinity of Erieau (grids 2128, 2230, 2240) and Patrick and Plum Points (grid 2275) followed by the occurrence of spent adults in those same areas supports the contention that spawning occurs in the vicinity of these catch locations.

Fish eggs were recovered along the length of the study area. The presence of walleye eggs among those collected was suspected; however, identification was not confirmed as only trout perch eggs were hatched in the laboratory after recovery from the lake bottom.

Larval and juvenile walleye were captured as far east as Port Glasgow (stations L8 and S12) and in the vicinity of Erieau.

Based on the above observations made during this survey which was exploratory in nature, walleye appear to experience some degree of reproductive success in the western part of the study area (vicinity of Erieau). This conclusion is supported by the presence of mature then spent adults, followed by the presence of larval walleye which in turn was followed by the presence of juvenile walleye in the month of July following spawning.

Although mature and spent adult walleye were observed east of Port Glasgow in the vicinity of Patrick and Plum Points, no confirmation of survival past spawning was obtained through capture of larval or juvenile stages.

RECOMMENDATIONS

Based on this study, several recommendations are made to make future studies more effective. In general, closer monitoring through the walleye's spawning and early rearing period is needed to assure collection of examples of each stage.

Spawning adults

Future studies should include:

- more commercial catch sampling to locate spawning activity;
- surface and bottom water temperature records at each catch site;
- a larger, randomly selected sample; and
- standardized and well-defined criteria for externally determining walleye sexual maturity.

Walleye eggs

Future studies should include:

- a sampling schedule based on the adult walleye sampling results; and
- positive fish egg identification by direct examination and by egg incubation and fry identification.

Larval walleye

Future studies should include:

- a sampling schedule based on adult walleye sampling results, fish egg collection results and water temperatures;
- adjustment of sampling location (surface, mid-water and bottom as well as inshore or offshore sites) based

on fish behaviour;

a record of surface and net-depth water temperatures for each tow;

a determination of the water volume sampled to derive catch per unit of effort values; and

discontinuation of sampling when plankton blooms interfere with the plankton net's effectiveness in capturing larval fish.

Juvenile walleye

Future studies should include:

a sampling schedule based on earlier results;

species identification and enumeration of all captured fish;

derivation of catch per unit of effort values for seine nets and trawl nets;

standardization of seining procedures (the boat-set seining method worked well in this study); and

the use of a larger boat to facilitate easier sampling site access and to enable trawl sampling of more varied substrate types.

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Table 1. Sexual maturity classification of adult walleye selected from commercial catches in the central basin, Lake Erie, 1984.

Date	Number examined			Percent							
				Immature		Maturing		Ripe		Spent	
	Male	Female	Sex unknown	Male	Female	Male	Female	Male	Female	Male	Female
April 27	3	4	0	0	25	100	75	0	0	0	0
28	1	9	0	0	0	100	100	0	0	0	0
May 3	4	20	4	0	75	100	15	0	10	0	0
5	0	25	0	-	52	-	40	-	8	-	0
6	0	19	4	-	47	-	47	-	5	-	0
7	14	24	1	0	17	43	17	36	38	21	29
8	0	5	0	-	75	-	0	-	0	-	25
9	1	24	0	0	4	0	8	0	0	100	88
11	1	1	0	0	0	100	0	0	0	0	100
Total	24	131	9								
Percent of total	14.6	79.9	5.5								

Table 2. Year-class composition, length-at-age and maturity of walleye selected from commercial catches in the central basin, Lake Erie, 1984. Numbers in brackets denote sample size.

Statistic	Age-group							
	II	III	IV	V	VI	VII	VIII	ALL
Percent of total	14.6 (23)	27.2 (43)	27.2 (43)	13.3 (21)	11.4 (18)	5.7 (9)	0.6 (1)	100 (158)
$\bar{L}$[a]	368	447	507	586	607	631	670	
Percent mature males	100.0 (6)	100.0 (9)	100.0 (6)	100.0 (5)	100.0 (1)	100.0 (1)	-	
Percent mature females	0 (14)	20.7 (29)	80.5 (36)	100.0 (16)	94.1 (17)	100.0 (8)	100.0 (1)	

[a] Mean total length ($\bar{L}$) is in mm.

Table 3. Fish eggs collected at selected sites in the central basin, Lake Erie, 1984.

Station	Sample number	Sampling depth (m)	Total number of eggs	Percent live eggs	Bottom type
E1	150584-01	2.1-5.5	0	-	Predominantly sand
E2	150584-02	2.1-6.1	0	-	Hard bottom
E3	150584-03	2.7-5.5	6	33	Sand/fine gravel
	150584-04	5.5-7.6	3[a]	100	
E4	150584-05	1.5-5.5	9[a]	100	Gravel/hard bottom
E5	150584-06	2.1-6.1	2	100	Gravel/sand
	230584-03	2.4-6.7	2	100	
E6	140584-01	3.7-5.5	1	100	Gravel/rough bottom
	140584-02	3.7-6.1	1	100	
	230584-04	2.1-4.9	13	77	
E7	140584-03	2.1-4.8	3	100	Gravel/sand/hard bottom
	150584-07	6.1-7.9	1	100	
	230584-05	2.4-5.5	2	50	
	310584-01	1.8-6.7	3	67	
E8	140584-04	1.2-3.7	3	100	-----
	230584-06	3.0-5.5	2	100	
E9	140584-05	1.2-5.5	4	100	Sand/clay
	230584-07	1.8-6.1	3	100	
E10	140584-06	1.5-5.2	4	25	Clay
	230584-08	3.4-6.1	0	-	
E11	140584-07	2.1-5.5	0	-	Sand
	230584-09	2.4-6.1	0	-	
E12	170584-08	1.5-4.0	0	-	Sand
E13	170584-07	2.4-5.5	0	-	Hard bottom/no gravel
	230584-02	1.8-5.5	0	-	
E14	170584-06	3.4-5.5	2	50	Clay/sand
	230584-01	3.7-6.1	0	-	
E15	170584-05	1.5-5.2	10	90	Clay
E16	170584-04	2.1-5.5	1	100	Clay
E17	170584-01	1.5-4.6	52	60	Hard bottom/little gravel
	220584-01	1.8-5.5	36[b]	75	
	300584-01	2.1-5.5	28[b]	89	
	300584-02	3.7-6.1	79[b]	100	
E18	170584-02	1.2-3.7	4	0	Hard bottom/some gravel/sand
	220584-03	2.4-5.5	4	100	
E19	170584-03	1.5-4.8	31	100	Very little gravel
	220584-02	3.0-4.9	19	74	

[a] Gelatinous masses of eggs, identified as those of yellow perch in early stages of development, were also collected at these sites.

[b] 104 eggs from these two samples were determined to be live in the field although only four hatched when incubated in the laboratory.

Table 4. Surface water temperatures, water depths and numbers of larval fish captured at selected sites in the central basin, Lake Erie, 1984.

Site	Date	Water depth (m)	Tow depth (m)	Surface water temp. (°C)	Yellow perch	Rainbow smelt	Walleye	Other[a]
L1	June 28	2.1-4.6	2.1-4.6	11.1				3
	June 28	8.2	4.3					
	June 28	15.2	4.0	12.8		1		3
	June 28	15.2	0.6		2			3
	June 28	18.3	0.3	20.0				
L2	May 31	4.3	4.3		7	2	1	
	May 31	9.8	9.8		3	50		
	May 31	On bottom			16	20		
	June 28	12.2	0.3	16.7	1			
	June 28	9.1	0.3	13.9		1		3
	June 28	4.6	0.3	19.4	2	4		1
L3	May 31	3.7	3.7		14	200		
L4	May 31	3.1	3.1		8	40		
L5	May 31	On bottom			1	80		
L6	June 6	3.7-4.6	3.7-4.6		20	10		
L7	June 6	2.1-3.1	2.1-3.1		30	15		
L8	May 30	4.0	3.1		10	50	1	
	May 30	3.1	3.1		5	30	2	
	June 6	2.4	2.4		50	3		3
	June 6	6.1	6.1		9	11		1
	June 6	8.5	4.3		4	20		
	June 19	3.1	3.1		15	10		5
	June 19	6.1	6.1		1			2
L9	June 6	2.4-3.7	2.4-3.7	13.9	30	60		3
	June 6	4.3-4.6	4.3-4.6		20	50		
	June 6	7.6	3.7		17	20		
	June 6	8.5	8.5		7	20		
L10	June 5	2.1	2.1		30	8		
	June 5	3.1-4.6	3.1-4.6		110	30		2
L11	May 30	6.1-9.1	5.8	8.9				
	May 30	6.1	4.9	8.9	1			
	May 30	3.1	2.1	8.9		6		2
	May 30	7.3	6.6	8.9	1			
	May 30	6.1	0.3	8.9		7		
	June 5	3.4	3.4		90	12		2
	June 5	5.2	5.2		100	35		3
	June 5	6.7	3.1		18	15		
	June 19	3.1	3.1	14.4	25	6		2
	June 19	5.5-6.1	5.5-6.1		6	30		1
	June 19	9.1	4.6		6	5		1
L12	June 5	2.4-6.1	2.4		20	10		1
	June 5	2.1-3.1	2.1-3.1	12.2	5	8		
	June 5	6.7	6.7		2	20		
Total					686	889	4	41
Percent of total					42.3	54.8	0.3	2.5

[a] Includes burbot and trout-perch, members of clupeidae, cyprinidae and percicthyidae families and unidentified fish species.

Table 5. Surface water temperatures, water depths and numbers of juvenile walleye captured with seine nets, at selected sites in the central basin, Lake Erie, 1984.

Site	Date	Water depth (m)	Surface water temp. (°C)	Walleye numbers	Others[a]
S1	July 18	1.2	13.5	0	present
S2	July 10	1.5	18.0	0	"
	July 18	1.2	14.0[b]	0	"
	July 25	1.8	19.0[b]	0	"
S3	July 18	0.9	15.0	0	"
S4	July 10	1.5	16.0	0	"
	July 18	1.5	15.0	0	"
S5	July 10	0.9	16.0	0	"
	July 18	0.9	14.0	0	"
S6	July 10	1.2	15.0	0	"
	July 18	0.9	14.0	0	"
S7	July 25	1.8	22.5[b]	2	"
S8	July 25	3.1	23.0[b]	0	"
S9	July 25	3.1	21.0[b]	1	"
S10	July 10	1.4	15.0	0	"
S11	July 17	1.2	16.0[b]	0	"
	July 24	1.5	19.0[b]	0	"
S12	July 24	2.4	19.0[b]	1	"
S14	July 17	0.8	16.0	0	"

[a] Others include rainbow smelt, yellow perch, white bass, white perch, logperch (Percina caprodes), trout-perch and members of centrarchidae, clupeidae, cottidae, cyprinidae, percichthyidae and percidae families.

[b] These samples were collected with a boat-set seine net, while the remainder were collected with a hand-set seine net.

Table 6. Surface water temperatures, water depths and numbers of juvenile walleye captured with a trawl at selected sites in the Central Basin, Lake Erie, 1984.

Site	Date	Water depth (m)	Surface water temp. (^{o}C)	Walleye numbers	Other[a] species
T1	July 31	3.1 - 4.6	22.0	1	present
T2	July 31	4.6	21.0	0	"
T3	July 31	4.6	21.0	0	"
T4	July 31	3.4	21.0	0	"
	July 31	1.8 - 3.1	21.0	1	"
T5	July 31	2.1 - 3.1	21.0	0	"
T6	August 1	3.7	20.0	0	"
	August 1	3.1	20.0	0	"

[a] Other species includes yellow perch, rainbow smelt, white bass, white perch, channel catfish (Ictalurus punctatus), trout-perch, spottail shiner (Notropis hudsonius) and gizzard shad.

Appendix I: Sites sampled to document the occurrence of walleye eggs in the central basin, Lake Erie, 1984.

Site	Site location	Latitude/longitude
E1	Morpeth access	42°22'28", 81°49'13"
E2	2.8 km east of Morpeth	42°23'31", 81°47'51"
E3	5.5 km east of Morpeth	42°24'31", 81°46'19"
E4	Palmyra	42°25'19", 81°44'42"
E5	Palmyra icehouse	42°25'36", 81°45'15"
E6	1.6 km w of Clearville (pinetrees)	42°25'54", 81°44'15"
E7	Clearville	42°27'11", 81°41'43"
E8	Kent - Elgin County line	42°28'18", 81°40'11"
E9	Humphrey's fishery	42°29'17", 81°38'18"
E10	2.6 km west of Port Glasgow	42°29'45", 81°37'42"
E11	Port Glasgow	42°30'24", 81°36'43"
E12	3.2 km east of Port Glasgow	42°31'49", 81°35'00"
E13	Leith fishery	42°32'28", 81°34'00"
E14	West Lorne pumping station	42°33'31", 81°32'47"
E15	4.9 km west of Patrick Point	42°34'00", 81°31'22"
E16	2.8 km west of Patrick Point	42°34'33", 81°29'49"
E17	Patrick Point	42°35'00", 81°27'59"
E18	Tyrconnell	42°35'48", 81°27'18"
E19	Plum Point	42°36'19", 81°23'56"

Appendix II: Sites sampled to document the occurrence of larval walleye in the central basin, Lake Erie, 1984.

Site	Site location	Latitude/longitude
L1	Morpeth access	42°22'28", 81°49'13"
L2	Clearville	42°27'11", 81°41'43"
L3	Kent-Elgin County line (3.2 km east of Clearville)	42°28'18", 81°40'11"
L4	4.8 km east of Clearville	42°28'52", 81°39'02"
L5	Humphrey's fishery (3.2 km west of Port Glasgow	42°29'17", 81°38'18"
L6	Port Glasgow	42°30'24", 81°36'43"
L7	3.2 km east of Port Glasgow	42°31'49", 81°35'00"
L8	Leith fishery (4.8 km east of Port Glasgow)	42°32'28", 81°35'11"
L9	West Lorne pumping station (7.2 km east of Port Glasgow)	42°33'31", 81°32'47"
L10	3.2 km west of Patrick Point	42°34'33", 81°30'20"
L11	Patrick Point	42°35'00", 81°27'59"
L12	Plum Point	42°36'19", 81°23'56"

Appendix III: Sites sampled with seine nets to document the occurrence of juvenile walleye in the central basin, Lake Erie, 1984.

Site	Site location	Latitude/longitude	Substrate type[a]
S1	MOE water intake - end of County road 10	42°15'52", 82°00'42"	Sand, gravel
S2	Kenterieau Park (Erieau) - west entrance	42°15'31", 81°54'58"	Gravel
S3	Kenterieau Park (Erieau) - west of pier	42°15'21", 81°54'33"	Gravel
S4	Rondeau Park - Interpretive center	42°16'55", 81°54'33"	Sand
S5	Rondeau Park - main beach	42°18'58", 81°50'31"	Sand
S6	Kent County Park - changehouse	42°20'57", 81°50'04"	Sand, gravel
S7	Kent County Park - east of Wilcox drain	42°21'16", 81°49'56"	Sand, gravel, rubble
S8	East of Langstaff drain	42°21'45", 81°49'40"	Sand, gravel, rubble
S9	Morpeth access	42°22'28", 81°49'13"	Sand, gravel, rubble
S10	Clearville Park	42°27'11", 81°41'43"	Gravel, rubble
S11	Port Glasgow (mouth of Sixteenmile Creek)	42°30'22", 81°36'46"	Sand, gravel, rubble
S12	Port Glasgow (west of harbour)	42°30'25", 81°36'40"	Gravel, rubble
S13[b]	Patrick Point (west of stream mouth)	42°35'30", 81°27'59"	Rubble
S14	End of Tyrconnell Sideroad	42°35'40", 81°27'35"	Sand, rubble

[a] Rubble size range is 7.6 - 25.4 cm, gravel size range is 0.2 - 7.6 cm, sand size range is less than 0.3 cm (Dodge et al 1982).

[b] This site was not seined, but the substrate type was recorded.

Appendix IV: Sites sampled with a trawl to document the occurrence of juvenile walleye in the central basin, Lake Erie, 1984.

Site	Site location	Latitude/longitude
T1	Kenterieau Park (Erieau)	42°15'29", 81°54'43"
T2	Rondeau Park - Interpretive Center	42°16'55", 81°54'33"
T3	Rondeau Park - Main beach	42°18'58", 81°50'31"
T4	Kent County Park	42°21'16", 81°49'56"
T5	Morpeth access	42°22'28", 81°49'13"
T6	Port Glasgow	42°30'24", 81°36'43"